JUNE 10, 1991

CHEMICAL & ENGINEERING

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Producers expect year-end rebound

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CHEMICAL & ENGINEERING NEWS

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LETTERS

CHEMICAL SAFETY

Perfluorinated organic compounds

The oxidation by molecular oxygen of a substrate in a supposedly inert perfluorocarbon liquid released considerably more energy than anticipated. Pressure and temperature far exceeded the expected values, leading to a potentially serious incident.

Subsequent conversations with knowledgeable coworkers elsewhere within Dow indicated that perfluorinated organic compounds are more reactive with oxidizers—particularly oxygen gas—than is widely believed. In view of the commonly held belief that such compounds are essentially inert, we strongly encourage anyone considering the use of these compounds in the presence of oxidizers to have appropriate reactive chemical evaluations done first.

We also ask that suppliers of such materials reevaluate their material safety data sheets to heighten users' awareness of the reactivity of perfluorocarbons with oxidizers.

Bob Dawe
Ram Gopal
Przem Pruszynski
Dow Chemical Canada Inc.
Sarnia, Ontario

Priestley Medal Address

I read with pleasure Harry B. Gray's Priestley Medal Address (C&EN, April 15, page 17) and his tribute to his mentors, teaching, research, and luck. It is with a mixture of amazement, disbelief, and nostalgia that I reflect on the differences between the support of science research then and now. Gray's reminiscence that his first grant from the National Science Foundation was actually invited by Oren Williams is remarkable by today's standards. Imagine that! An NSF or National Institutes of Health project director calling you up and saying they'd like to give you some funds for research.

If the report from the American Association for the Advancement of Science is correct and the senior scientists in our country are discouraged, how should their younger peers feel? My experience has probably been similar to many younger (under 40) researchers. This past year alone I have submitted eight different grant applications to private and public funding sources only to be approved for funding, but not funded. As children we learned that close only counts in horseshoes and hand grenades. To be ranked seventeenth on a list of approved grants by one agency, which then funded only 16 grants, was a mega-disappointment. After three years of grant writing, I have received one $10,000 award from an external agency, which was appreciated, but the return per hour spent writing proposals was very low.

Daniel Kleppner presents a fine analysis of the funding squeeze on basic research in "The Mismeasure of Science" (*The Sciences*, May/June 1991, page 18) where he tracks where the governmental research funding priorities lie today. With two thirds of the recent past and present federal R&D expenditures going toward defense projects such as the B-1 bomber, 96 out of 100 of which are grounded; with the B-2 bomber, which will be scuttled; with the Navy A-12 plane, which has been aborted; with a space station project that consumed $1.9 billion last year; with assorted projects of the National Aeronautics & Space Administration, Star Wars, and Antarctic exploration, I have little wonder why basic research dollars are so few. (Perhaps the military would let NSF or NIH sell those planes for spare parts, and then use the funds for basic and medical R&D?) In addition, with a $210 billion annual interest on our national debt and the country in a recession, there will be no significant increase in basic research dollars unless the governmental priorities change dramatically.

Why then do I and many of my peers still persist in this quixotic fashion: underfunded, overstressed, often underpaid, and looking toward a bleak national future? I think Gray is correct in that most of us stay in research and education because we are "doing something that is so much fun." I think scientists still work with the hope that our efforts will push back the frontiers of knowledge, educate, and maybe even help people. (We are also overqualified to sell shoes or auto parts, and too proud to beg on the street.)

The tragedy that lies ahead is that we will not be able to inspire, encourage, or

Booming MTBE Demand Draws Increasing Number of Producers

Starting as an octane booster and developing to clean fuels component, MTBE is industry darling—demand for it is likely to increase 25% by 1995

Susan J. Ainsworth, C&EN Houston

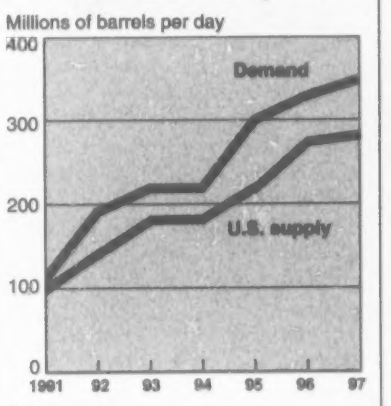
Methyl *tert*-butyl ether (MTBE) holds a highly esteemed position in the chemical industry: It has been the fastest growing chemical of the 1980s and it likely will continue to hold that distinction throughout the 1990s. Just how high MTBE's demand growth rate soars will depend on a number of complex factors, but some sources say it could potentially top 25% per year by 1995.

"MTBE is unique in that it basically started as an octane blending component and [now] 10 years later the primary use has started to change to that of a clean air component. I can think of no other chemical that has experienced this unique growth profile," says Bill Ludlow, a vice president at DeWitt & Co., Houston, who spoke at the consulting firm's 1991 Far East Petrochemical & Gasoline Review in Singapore last week.

An increasing number of companies are making the same observation and are finding the market for the octane booster irresistible. Right now, there are no U.S. plants solely dedicated to MTBE. Soon there will be at least five big ones. Tenneco Gas' natural gas liquids/methanol unit claims it will build the first such plant by mid-1992 at LaPorte, Tex. Coastal Chem Inc. plans to complete its unit by spring 1992 in Cheyenne, Wyo. Also sometime next year, Global Octanes' MTBE unit at Deer Park, Tex., is slated for completion. In 1993, Valero Energy plans to finish one at Corpus Christi, Tex., and the newly formed Freedom Group in Philadelphia plans to have an MTBE unit running at Morris, Ill., later that year. These plants alone will add a total of 55,100 barrels per day of MTBE to the 100,000 bbl per day that is current domestic capacity.

The activity seems to be just beginning. More companies are reportedly poised to jump on the production bandwagon, assuming they can secure financing, permits, equipment, and raw materials. For example, DeWitt says it is working with four more companies that are thinking of building grass-roots facilities. Engineering and construction company M. W. Kellogg, which is working under its third MTBE plant contract, says it is also conducting confidential studies with companies still pondering investment in new units for the chemical.

MTBE supply, demand to more than double by 1997



Source: Tenneco

In addition, many more companies are boosting MTBE capacity at existing facilities. These capacity additions, which average about 2000 to 3000 bbl per day, are "slam dunks for refiners," says Ludlow. These moves cost only about $15 million each, so "you can expect that almost every refiner with a fluid cracking catalyst unit will make the move if they have not already." Those small additions alone will add roughly 100,000 bbl per day to domestic capacity through 1993. In addition, new and existing facilities may be able to squeeze out even more product, thanks to a higher yielding technology unveiled just two weeks ago by UOP Inc., a joint venture of Allied-Signal and Union Carbide.

Despite the wave of construction, U.S. producers of MTBE will not be able to single-handedly meet soaring demand for MTBE in winter 1992, when the Clean Air Act mandated oxygenate requirement for carbon monoxide nonattainment areas takes

Five firms plan to build MTBE capacity in U.S.

	Site	Daily capacity (barrels per day)	Cost ($ millions)	Completion
Coastal Chem	Cheyenne, Wyo.	4,600	$ 72	Spring 1992
Freedom Group	Morris, Ill.	12,500	300	Late 1993
Global Octanes	Deer Park, Tex.	12,500	200	1992
Tenneco Gas	LaPorte, Tex.	12,500	160	mid-1992
Valero Energy	Corpus Christi, Tex.	13,000	230	mid-1993
TOTAL		55,100		

Sources: Company statements, DeWitt & Co.

Regulations continue to spark MTBE demand

Demand for the world's fastest growing petrochemical, methyl *tert*-butyl ether (MTBE) has been largely driven by regulations. In the 1980s, refiners turned to MTBE to replace the octane lost when the U.S. government initiated a lead phasedown for gasoline. And now, MTBE is entering its second growth stage, which will stretch well into the 1990s. MTBE will now also be used as an oxygenated fuel additive needed to reformulate gasolines so that they meet requirements under the Clean Air Act amendments that take effect in 1992, says Bill I. Ludlow, a vice president at DeWitt & Co. (Houston).

The first phase of attack by the Clean Air Act amendments involves 44 areas of the country that have not met the carbon monoxide (CO) emission standards set by the Environmental Protection Agency (EPA). Beginning in November 1992, it will be necessary for these areas to sell gasoline that has at least 2.7% oxygen content during winter months. David E. Gushee at the Library of Congress' Congressional Research Service in Washington, D.C., believes oxygen will be supplied in either one of two forms: ethanol or MTBE. Methanol, *tert*-butyl alcohol, ethyl *tert*-butyl ether, methyl *tert*-amyl ether, other ethers, and mixtures of these will also play roles, he says.

However, this first deadline could change. According to Gushee, the Clean Air Act amendments give EPA the authority to waive for one year (with the possible extention of one additional year) the oxygenate requirement subject to specified findings. "There are two bases on which this waiver can be granted: inadequate domestic supply of or distribution capacity for oxygenated gasoline or oxygenates," he says. "The biggest issue in the phasing in of oxygenated fuel is the meaning of 'inadequate domestic supply.' "

It's likely the refining industry will have to wait until EPA's final rule-making deadline of Nov. 15 to find whether the agency will grant a waiver, Gushee conjectures. Although EPA reportedly completed a proposal on this issue late last month, it "is being closely guarded" at the Office of Management & Budget, says Gushee. "I'll make a bet that EPA is leaning toward defining domestic supply in an expensive way," including product that "could be shipped from somewhere else in the world." That would mean the affected areas would have to be in compliance by winter 1992. He reasons that EPA will feel pressure to more rigidly uphold the Clean Air Act mandates simply because it is the agency responsible for cleaning up the air and environment. Even if EPA takes a stand on this issue now, as oil companies have asked it to for planning purposes, "a cloud of uncertainty will hang over this issue until November due to its controversial nature. And that uncertainty will have an effect on private-sector planning."

Although the oxygenate initiative is starting with gasoline in CO nonattainment areas, explains Gushee, it will soon spread to ozone nonattainment areas, which represent larger parts of the gasoline market. Beginning in January 1995, the nine worst ozone nonattainment areas must sell reformulated gasoline containing at least 2% oxygen content year round. Six of these areas also happen to be CO nonattainment areas, and so will already be selling oxygenate-rich gasoline to meet the 1992 deadline, he adds. Besides 2% oxygen, the new ozone law requires that reformulated gasoline have a maximum benzene content of 1% and a maximum aromatics content of 25%. "Just as hotly contested as the domestic supply issue is the question of how reformulated gasoline will ultimately be defined by EPA," Gushee notes. The refining sector is anxious to know which oxygenates will be suitable and how much it will cost to comply, he says.

"Since the U.S. currently consumes over 7 million barrels per day of gasoline and is the largest gasoline market in the world, [these two mandates will create demand for] large amounts of MTBE equivalents," says DeWitt's Ludlow. He points out if moderate ozone areas decide to "opt in" and use oxygenated fuel voluntarily, demand will climb even higher. But, he says, it is conceivable that "politicians in a compliance area might, for publicity's sake, make an issue of opting in to get this new 'clean gasoline.' "

effect. According to DeWitt estimates, U.S. production of MTBE will grow from 100,000 bbl per day currently used for octane applications to at least 250,000 bbl per day by the end of 1993, assuming an average operating rate of 78%. But Ludlow estimates U.S. MTBE demand will blossom to at least 327,000 bbl per day as soon as the end of 1992.

In order to satisfy 1992 winter demand, it will be necessary to operate the existing MTBE plants all year and to store product for the peak winter month uses, says Ludlow. A rough estimate is that the U.S. will have to store at least 20 million bbl of MTBE to produce the required amount of oxygenated gasoline for next year. Producers are moving on this and have significant amounts in storage already, he notes.

In addition, it will be necessary to bring in MTBE from other countries' plants, he adds. A number of overseas facilities are going up, undoubtedly with an eye on the U.S. market. For example, National Methanol just awarded a contract to Fluor Daniel to build a 700,000 metric-ton-per-year grass-roots MTBE plant in Al-Jubail, Saudi Arabia. And Mobil Corp. and Chemvest, a Saudi Arabian petrochemical investment firm, expect to complete engineering studies by year's end for one of the largest MTBE plants in the world, which would likely be in Yanbu, Saudi Arabia. Late last year Kellogg began design and construction work on an MTBE-propylene plant for MTBE Malaysia in Kuantan, Malaysia.

The U.S. could successfully import MTBE simply because producers can fetch a good price. "Since late last year, spot MTBE has been selling at higher-than-octane value. This is because in the U.S., both MTBE producers and refiners realized MTBE is really no longer just an octane component; it is a clean air component," says Ludlow.

Accordingly, he notes, the price formula for MTBE and most large contracts have changed from an octane formula. Essentially, producers have incorporated rack gasoline

prices—those charged by refiners at their terminals and traditionally higher than wholesale prices—into the formula. The result: The price of MTBE has risen roughly 10 to 12 cents per gal. "Even though there were some objections by the oil companies to this new formula, they generally accepted it," says Ludlow. "They realized that paying a higher price for MTBE was more acceptable to them than being forced to use alternative fuels."

Demand for MTBE will continue to rise sharply into the mid-1990s. By 1995, as the year-round ozone requirements of the Clean Air Act amendments go into effect, Ludlow predicts U.S. demand will reach 388,000 bbl per day in the winter and 164,000 bbl per day from March through October. That estimate could get even larger if some areas decide voluntarily to buy the cleaner oxygenated fuel, he notes.

These demand scenarios are great news for the construction industry. "To meet U.S. demand over the next five years or so, there will be a need for at least another dozen plants," says a Kellogg spokesman. These plants, some of which might be built outside the U.S. with export capabilities, would need to produce on the order of 12,000 bbl per day, about the capacity of those now being built. "So we're talking about several-billion-dollar investments that will be made just to meet U.S. demand. And on top of that, demand in Europe is growing, too."

Increasing MTBE imports and the seasonality built into the 1992 carbon monoxide requirements alone will create opportunities for storage tank manufacturers and terminal operators, notes Paul Fields of Houston-based Pace Consultants. He notes that although MTBE is stable and presents no storage problems, "our analysis indicates that [storage] is somewhat impractical, because of the large amount of tankage required." But, he adds, "this will happen to some extent, however, presenting an opportunity for tank manufacturers and terminal operators."

Obviously recognizing this niche early on, Texas Eastern Products Pipeline Co. (TEPPCO) recently unveiled plans to store and transport via pipeline increasing quantities of the chemical (C&EN, May 20, page 6). Says TEPPCO vice president David L. Langley: "Pipeline transfer, which is one of the most efficient means of MTBE transport, will play an important role as regional demand begins to exceed a region's supply, and the availability of efficient and cost-effective logistics becomes the limiting factor in its usage."

Another, more critical limiting factor in the supply of MTBE may be feedstock availability. For example, early last month the National Petroleum Refiners Association (NPRA) released an MTBE plant survey that revealed unexpectedly low capacity utilization rates averaging 63.6% over the three-year period 1988–90. NPRA says it received responses from all 22 captive MTBE plants in the U.S. The primary factor resulting in low utilization was feedstock availability.

"The biggest concern right now is supply of methanol," a key raw material for the production of MTBE, says Ludlow. There is some reluctance on the part of methanol producers to commit to new plants. Ten years ago, many plants were built to supply the expected demand for methanol as a gasoline additive, but that demand did not materialize, he explains. "The same guys that had to go to the board 12 years ago and ask for the money for those failed plants don't want to have to go back again." But that hesitance is subsiding and a lot of plants are starting to come on-line, according to Roy Sugimoto, a consultant with expertise in engines and fuels at DeWitt. That's because the price of methanol has

UOP unveils high-yield oxygenates process

Just as demand for oxygenates is booming, UOP Inc. has unveiled a new, high-performance process for producing oxygenates methyl *tert*-butyl ether (MTBE), ethyl *tert*-butyl ether (ETBE), and methyl *tert*-amyl ether (TAME) from isobutylenes and isoamylenes. The new process, called Ethermax, is designed to produce higher yields of C_4 and C_5 ethers with lower investment and operating costs than other etherification technologies. Says Steve T. Bakas of UOP's MTBE marketing group: "We expect significant interest in the Ethermax process for MTBE/TAME production because of the Clean Air Act in the U.S. and a growing emphasis worldwide in the use of oxygenates in gasoline."

The Ethermax process is the result of the joint efforts of Germany's Hüls A.G. and Koch Engineering Co., Wichita, Kan., as well as UOP, a joint venture of Allied-Signal and Union Carbide based in Des Plaines, Ill. The new process combines the engineering design and operating experience of UOP and Hüls with Koch's proprietary reaction with distillation (RWD) technology.

The RWD technology makes use of Katamax structured tower packing, Koch's dual-function, mass transfer/catalyst contacting equipment. Katamax packing provides efficient mass and heat transfer between vapor, liquids, and solid catalyst, accomplishing effective fractionation and olefin reaction in a single zone. This technology achieves higher ether production by overcoming the equilibrium limitations of single-stage, fixed-bed processes. Compared with conventional single-stage technology, an Ethermax unit can increase isobutylene conversion from 96 to 97% by weight to more than 99% and can increase isoamylene conversion from 70% to 91%.

The process involves reduced equipment investment, in most cases, because reaction and distillation are combined in one vessel, compared with the need for two reactors with conventional technology. It also has a reduced catalyst requirement, compared with conventional technology, says UOP.

Several companies are "actively looking at this process now, but it is too early in the game for any of them to have finished their evaluations," says Bakas. One of those companies is Tenneco, which has begun construction of its 12,500 bbl-per-day MTBE plant at LaPorte, Tex. UOP estimates Tenneco could produce an additional 300 bbl per day at its new plant should it decide to incorporate the new technology. The Ethermax process will be available for all future MTBE, ETBE, and TAME units and for retrofits of existing units, says UOP.

cycled and is now up to more than 60 cents per gal, he says.

Sources are more mixed about whether supply of isobutylene, the other key raw material in production of MTBE, will be much of a problem. This really relates back to the supply of butane, which is isomerized and dehydrogenated in some processes to make isobutylene. Sugimoto says his research indicates there's probably enough butane readily available to satisfy demand.

It's not surprising that the companies that have committed to new MTBE units have feedstock and transportation or storage advantages. Says Kenneth W. Reese, vice chairman of Tenneco Inc., parent company of Tenneco Gas: "We're entering a market that is going to grow quickly, and we're entering with several competitive advantages that will allow us to be out in front of the wave, not caught up in it."

Tenneco Natural Gas Liquids produces isobutane at its LaPorte complex, site of the proposed facility; it makes methanol at the company's nearby plant in Pasadena, Tex. Plus, the company says it will use its LaPorte distribution facilities for rail, truck, and barge shipments of MTBE as well as the company's product pipeline network to transport MTBE to terminals and refineries in the Houston area.

For its part, Coastal Chem is touting its $72 million, 4600 bbl-per-day Cheyenne unit as "the first fully integrated MTBE complex in the world." The facility will go up adjacent to its existing agricultural products plant. Coastal's plant will rely on butanes coming from Wyoming gas-processing plants. It will have the advantage of not having to get its methanol from an outside source like most producers; it is building a 26 million gal-per-year methanol unit on site. Both natural gas and butane feedstocks will be delivered by parent Coastal Corp.'s Colorado Interstate Gas Co.

Another factor on Coastal's side: the location of the new unit. MTBE is already used extensively in the Rocky Mountain region to achieve mandatory oxygen content requirements during winter months in order to reduce carbon monoxide levels, according to Mike Ray, executive vice president and chief operating officer of Coastal Chem.

Global Octanes' Deer Park, Tex., facility will have the advantage of being a neighbor to the Intercontinental Terminals facility in Houston. "That means that [Global Octane] can buy isobutane right off the pipeline, eliminating the need for an isomerization unit, which saves it quite a bit of money," notes Ludlow. And that location is a big plus, he adds, considering "that much of the cost of producing MTBE lies in the tankage and storage of not only the raw materials but also of the finished product."

Meanwhile, Valero has access to large quantities of butane, which it will convert into MTBE at its 13,000 bbl-per-day, $230 million plant. It will get 100% of the butane needed for the project from its own operations—Valero Natural Gas Partners and Valero's refinery.

Although feedstock sources may be close at hand for these companies, the speed with which the number of MTBE plants now under construction or in engineering can be completed depends on several conditions such as securing the proper financing as costs rise, getting the necessary permits in a timely fashion, and finding a place on an engineering and construction firm's schedule. "The lead times [for plant construction] are certainly longer than they were even two years ago," adds Ludlow.

Prospective MTBE producers are also apprehensive about whether EPA will opt to waive the Clean Air Act oxygenate requirement for one or two years, softening 1992 demand for MTBE. "A delay would put companies that have invested in plants at a competitive disadvantage. So, some companies have a wait-and-see attitude," says one source.

Still, some observers say it's hard to envision a domestic oversupply of MTBE right now. "I cannot foresee MTBE being long in supply until the latter half of this decade," says Charles L. McSpadden, vice president of market analysis at Bonner & Moore Associates, Houston. "If we were to use only domestic MTBE, we would have to double or triple capacity in the next five years, and that's very tough to do" given the constraints on building a plant quickly (such as financing, rising costs, equipment availability). "MTBE [supply] will be tight throughout most of this decade, as far as I can see."

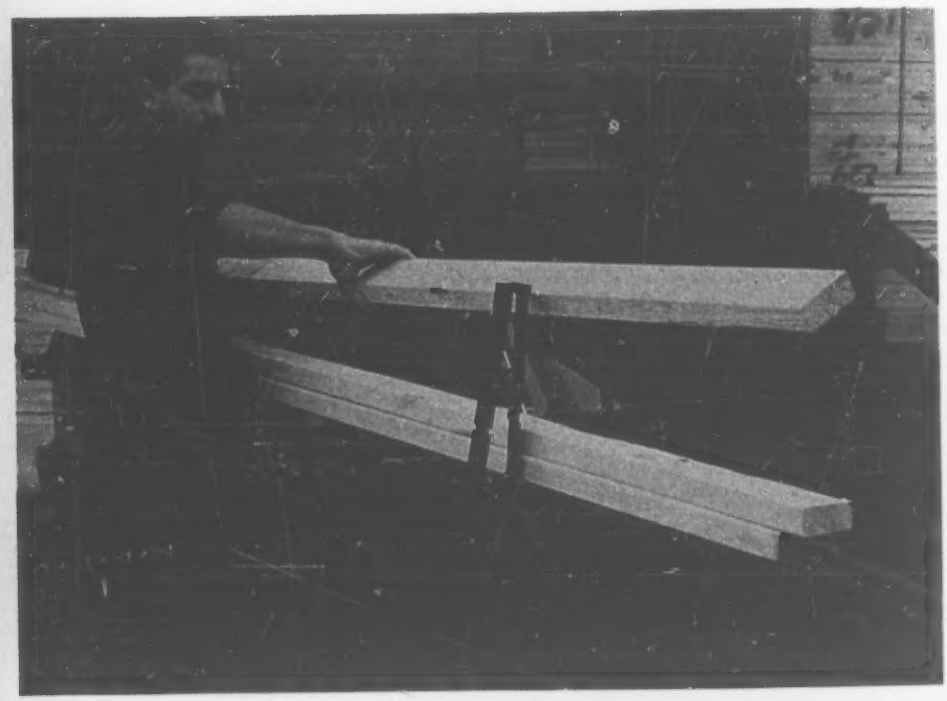
There's always going to be demand for MTBE, argues DeWitt's Sugimoto, because it is useful as a high-octane blendstock. When the government takes aromatics out of gasoline as part of the 1995 reformulated gasoline mandate, MTBE will help offset the resultant octane loss, he says.

Also, MTBE is favored over alcohols as both an octane booster and an oxygenate. That's because direct blending of alcohols presents problems, including high blending vapor pressures, water affinity, and associated phase separation. Also, methanol is incompatible with some fuel system components and poorly accepted by consumers, according to McSpadden. The more favorable outlook for fuel ethers is based on several attributes: little or no water solubility problems and general acceptance of ether-gasoline blends, he adds.

In addition, MTBE blends like a hydrocarbon and requires no extraordinary handling procedures by the refiners, adds Ludlow. "And MTBE is a fungible product," which means it is interchangeable and is accepted by all refiners. This makes the trading of gasolines in the U.S. system workable, Ludlow says. And MTBE has an edge over other ethers such as ethyl *tert*-butyl ether and methyl *tert*-amyl ether, in that MTBE is currently more readily available, Sugimoto says.

Ironically, although new and rigorous government regulations have been making life miserable for producers of a host of chemicals, new regulations continue to be the source of prosperity for MTBE producers. The icing on the cake is that MTBE producers can also get a lot of public relations mileage out of their participation in a business with positive environmental implications. Tenneco vice chairman Reese sums it up well: "When our financial and environmental goals complement each other, as they do here, it's a powerful combination. We make a return on our investment, and society lives in a protected environment." □

Plastics Producers Look For Turnaround by Year's End



Mobay photo

Twin U-shaped auto carrier racks for transporting extra-long items are molded of tough nylon resin

Bruce F. Greek, C&EN Houston

Demand and production of plastics slipped into the down phase of a business cycle early this year, but they're likely to turn back up as early as the third quarter. Currently industry sources believe that demand, output, and pricing are at the year's nadir.

The downturn is expected to be enough, however, to cause 1991's total output of plastics to fall slightly from last year's. Most producers estimate a decline of less than 1%, or about 500 million lb, from the 60 billion lb or more of total production estimated for last year.

Estimates of total plastics output are all that's available because the official reports on plastics production compiled by the accounting firm Ernst & Young for the Commitee on Resin Statistics of the Society of the Plastics Industry (SPI) and statistics gathered by the U.S. International Trade Commission omit some of the numerous small-volume plastics. Including these, guesses by industry sources of total 1990 output are in the 60 billion to 65 billion lb range.

If demand strengthens beyond current expectations, output of a few resins could turn up slightly this year. Higher demand at a time when inventories are low could spur producers to operate plants at production levels higher than are now forecast for the third and fourth quarters.

Over the longer term, the majority of plastics will continue their traditional growth in demand and production. Most sources forecast this growth rate will be lower, however, than in the 1980s.

Several environmental actions are beginning to reduce growth from the levels previously forecast for the 1990s and beyond. For example, paper, glass, and metals are now substituting for plastics in some uses. And recycling of plastics and outright bans on certain types of plastics are depressing growth.

However, the decline in plastics production this year is generating less concern among producers than is the slump in selling prices. All large-volume resins currently are selling below their posted prices. And selling prices continued to fall this spring, especially in export markets. The difference between contract and actual selling price varies among these resins but ranges from 10 to 25%.

Many small-volume plastic products—for example, engineering and specialty resins—are faring slightly better in maintaining sales volume and prices. Epoxy and acrylonitrile-butadiene-styrene (ABS) resins are experiencing sales and price declines similar to the polyolefins. The truly specialty resins, those having very small volumes, are posting gains owing to the development of special niches. Similarly, sales of some blends and alloys of plastics are showing gains, while those of other types are declining.

HDPE: blow-molded items keep growth high

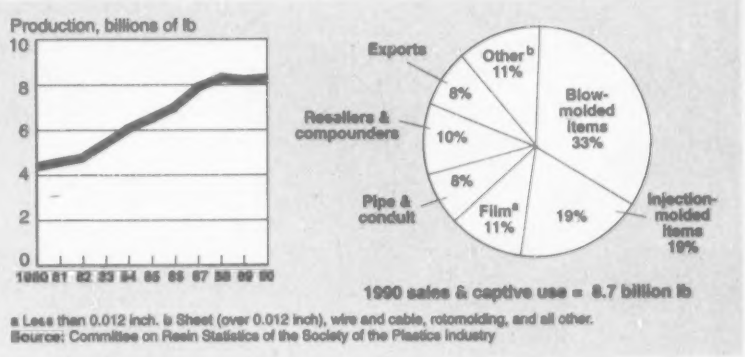
U.S. demand for high-density polyethylene (HDPE) is expected to exceed 10 billion lb in 1995, up from over 8 billion lb forecast for this year, which is 30% of global demand of about 27 billion lb. Widespread plant construction will allow capacity to grow and keep pace with or exceed demand.

All major uses of HDPE except exports will grow substantially, says Dennis L. Rohlfing, resins marketing manager of Phillips 66. Blow molding and injection molding have the largest share of uses and are expected to grow 3 to 4% annually over the next five years. Film and sheet uses will grow 9 to 10%, Rohlfing forecasts.

Blow molding, consuming about a third of U.S. HDPE, will have much of its demand growth concentrated in food bottles and auto gas tanks. Containers for products other than milk also contribute to blow molding use. If resin supply continues to be ample and prices rise only slightly, increased conversion of half-gallon size milk bottles to HDPE could stimulate growth. Consumption in motor oil bottles rose from almost nothing in 1985 to 300 million lb in 1989. This use could decline because increased amounts of recycled resin are being used and because of a shift toward bulk delivery of lubricating oils to "quick-change" shops.

Injection molding will require about 1.8 billion lb of HDPE in 1995. Pails for packaging applications, thin-walled food containers, and a large number of consumer and industrial uses will lead growth in this use, says Rohlfing.

Most recycling of HDPE will be blow-molded and injection-molded items. By the year 2000, half of some fabricated products, such as milk and motor oil bottles, will be recycled, he forecasts.



a Less than 0.012 inch. b Sheet (over 0.012 inch), wire and cable, rotomolding, and all other.
Source: Committee on Resin Statistics of the Society of the Plastics Industry

Sales managers are cutting contract prices for large-volume plastics in an attempt to bring them closer to actual prices. Price reductions in March and April were larger than those for preliminary prices for May. The inventory liquidation by consumers that began in late 1990 has further reduced sales. Most industry sources agree that further lowering of prices may occur, but they doubt that it will be as large as the earlier drop.

Because inventories are low and the recession likely has bottomed out, there is some optimism for the rest of 1991. Inventories of the size and extent of the past's may be over. Both plastics producers and fabricators now can't afford the cost of maintaining large inventories, especially of lower volume grades. When demand increased significantly, as it did after previous slumps, inventories then proved worth more than their maintenance cost in avoiding lost sales, point out several industry sources.

Lower selling prices have caused profit margins for plastics to slip dramatically since late last year. Earnings for many of the producers have dropped more than prices and margins, reflecting the difficulty of reducing monomer and other manufacturing costs as rapidly as sales dollar volume declines. Cost-cutting programs are helping somewhat. These programs are forecast to increase profit margins by a large amount later in 1991 and into 1992 (when demand growth is expected to resume).

The drop in selling prices and margins has its source in more than a slowdown in demand. Completion of additional capacity, increasing competition with other nonplastic materials, and competition among polymers also have caused the price cuts designed to gain market share and capture new markets. Competition among polymers has rapidly increased the number of different grades of plastics that are available. Newly commercialized polymers also are being pushed into existing markets. Although margins that provide investment for new polymers and their commercialization are narrowing, these numerous developments continue.

Lower selling prices and plant operating rates for most plastics, especially thermoplastics, now have profit margins perilously near breakeven. Cash costs (for monomers and manufacturing but not for depreciation) temporarily may be higher than selling prices in some cases, as producers seek to sell additional pounds of plastics. Export sale prices and returns after paying freight and insurance have been particularly hard hit by competition from areas needing hard currency.

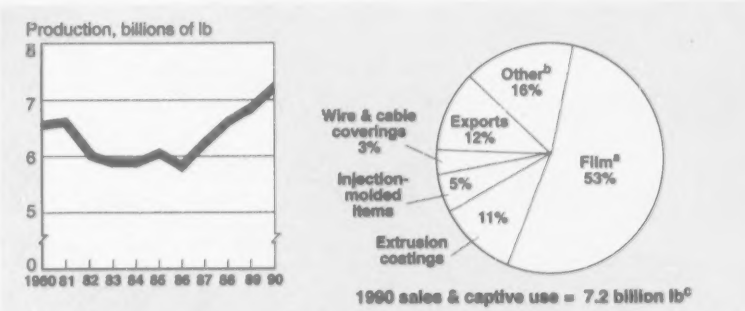
Export sales have long been a way of bolstering production when domestic markets are weak. Following declines that began more than a year ago, two important sectors of the domestic market for plastics—building and construction and transportation equipment—are still weak. Building and construction accounts for more than half the use of polyvinyl chloride (the largest volume thermoplastic) in pipe, siding, and wire and cable covering, according to data compiled by Ernst & Young. Unless construction (particularly housing) increases faster than during the first quarter of this year, PVC consumption will be lower than last year.

Despite efforts to increase exports, plant operating rates are significant-

LDPE: aging polymer still growing

Output of low-density polyethylene (LDPE) is growing again after declining for several years as a result of the partial shift toward linear low-density polyethylene (LLDPE). Limited by capacity restraints, U.S. demand will continue to increase, averaging more than 2% annually over the next five years. Other polyethylenes now are seldom substituted for the low-density material. Special properties available from the highly branched structure of LDPE are unobtainable in other polyethylenes.

The economics of operating aging plants, use of LDPE to avoid paying for more costly resins, and the profitability of investment returns from available prices will determine how long the rising demand can be supplied. If manufacturing costs of this resin go up, the lower value markets will be forced to pay more or find alternative materials, says David L. DeMocker, LDPE product manager at Dow Chemical. Sales of the resin as a uniquely designed product will then increase.



a Less than 0.012 inch. b Sheet (over 0.012 inch), blow molding, pipe and conduit, other extruded products, adhesives and sealants, resellers and compounders, and all other. c Including imports. **Sources:** Committee on Resin Statistics of the Society of the Plastics Industry, SRI International, Union Carbide, C&EN estimates

As developing markets in the Pacific Rim and Latin America grow, export demand for LDPE will remain strong, says DeMocker. Less sophisticated equipment and available technical service in those countries will cause an even greater need for its ease of processing.

Because of higher returns, more of the high-pressure process technology (by which LDPE is made) is being converted to make ethylene copolymers, points out DeMocker. The copolymers are more difficult to produce and require slower production rates, effectively reducing capacity. Therefore, he says, the future supply-demand relationship will become tight for this plastic despite incremental capacity expansions.

ly down from peak levels. Except for high-density polyethylene (HDPE), the rates range from 70 to 80% of nameplate capacity. The HDPE operating rate at the end of the first quarter was above 80%. These rates generally are expected to decline during this year, as new capacity comes on stream and plant process improvements are completed. For most of the large-volume thermoplastics, planned capacity expansions are relatively small. Capacities to make HDPE and polypropylene are exceptions. Although other planned expansions are small, they will be added at a time when demand growth will be yet smaller.

However, digesting the expansions that have been or are being built in the two-year period 1990–91 is difficult at this time. For example, nameplate capacity to make HDPE will increase 3.2 billion lb, or 40%, between the beginning of 1990 and the beginning of 1992 to reach more than 11.1 billion lb, according to data compiled by Pace Consultants. The capacities for the low-density polyethylenes (LDPE) will grow considerably less during the same time, about 1.3 billion lb or 10%, says Hugh S. Pylant, a senior consultant at the firm. Capacity for both polypropylene and PVC will be increased about 1.6 billion lb, or 18% and 15%, respectively. Only polystyrene capacity will grow marginally, with an increase of about 250 million lb, or about 4%, to bring the total to more than 6.7 billion lb by the beginning of 1992.

Reflecting demand, production of these large-volume thermoplastics (except for HDPE and polystyrene) increased by large amounts in 1990. Because of Phillips' loss of a major HDPE plant in an explosion and fire in Deer Park, Tex., late in 1989, output of this resin has been limited by a lack of capacity. Had demand growth held up this year, production of the thermoplastics may have increased by substantial amounts to cover at least part of the new capacity. Because of the slump in demand, however, output of many thermoplastics is expected to be down this year. Therefore, the average growth over 1990 and 1991 will be well below capacity expansions during that same time.

Except for exports, all of the major uses of ABS and other styrenic polymers (such as styrene-acrylonitrile) fell early this year. Exports were up about 25%, to more than 60 million lb, or nearly 20% of sales and captive use. The jump in exports shows that they are crucial in maintaining output for these mature plastic resins.

Exports also have been important to other thermoplastics, enabling some to buck the trend of lower production and sales. Exports of both nylon and thermoplastic polyester resins have increased substantially this year, after posting gains in 1990. Nylon exports amount to more than 15% of sales and captive use that includes imported material. Thermoplastic polyester exports will account for about 30% of sales and captive use this year, compared with about 20% last year. The polyester export growth this year offset declines in domestic uses and provided gains in total sales and production over the first quarter of last year.

The nylon demand situation differs from that of polyester. So far this year, domestic consumption of nylon has been holding up well, de-

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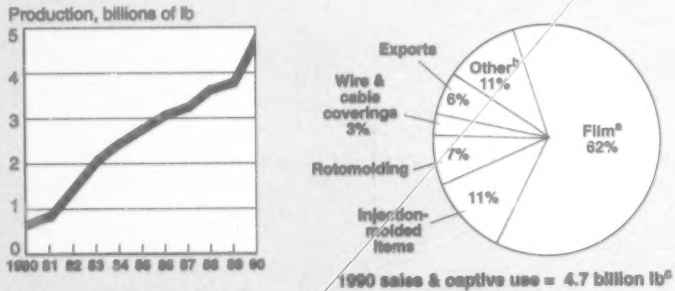
LLDPE: film use propels high growth rates

In the past decade, demand for linear low-density polyethylene (LLDPE) jumped from less than 750 million lb to more than 4.7 billion lb, an average annual growth rate of about 20%. Such growth will not be sustained during the rest of the 1990s, but growth nevertheless will be substantial.

In most areas of the world, LLDPE growth will significantly outpace other competing large-volume plastics, such as conventional low-density polyethylene and high-density polyethylene. New capacity is under construction at numerous locations. Often this is "swing" capacity that can be used to make either LLDPE or HDPE.

Assuming that growth for low-density polyethylenes is 2.5% annually for the U.S., Canada, Western Europe, and Japan, and is 5% annually for the rest of the world, global demand can be expected to rise from about 41 billion lb in 1990 to about 57 billion lb in 2000, says Ronald J. Cottle, business manager for polyolefins at Union Carbide. If, as has been occurring, the LLDPE gets most of the increased demand, the average growth rate would be more than 15% annually; if it gets half, the rate would be more than 7% annually, Cottle points out.

Film dominates use of LLDPE. It also is the fastest growing use. However, the surge in 1990 reflects a film inventory reduction in 1989, Cottle says. Exports remain the other fast-growing use. Exports doubled in 1989 and increased from 174 million lb to 255 million lb in 1990.



a Less than 0.012 inch. b Sheet (over 0.012 inch), blow molded items, pipe and conduit, resellers and compounders, and all other. c Including imports. **Sources:** Committee on Resin Statistics of the Society of the Plastics Industry, SRI International, Union Carbide, C&EN estimates

spite declines in sales of various kinds of durable goods containing parts made of nylon (such as automobiles and appliances). If demand for nylon continues at current levels and then picks up (if the recession ends this fall as expected), then sales and captive use of nylon resins could tack another small gain to the more than 580 million lb of record sales in 1990.

Nylon 66 (salt of adipic acid and hexamethylenediamine) and nylon 6 (caprolactam) comprise about 90% of nylon resins consumption. The several other nylons, fabricated mostly for specialty uses in the same general use categories as nylon 66 and nylon 6, account for the remainder.

Various injection-molded items accounted for more than half of 1990 nylon consumption, according to SPI data. A diverse range of automotive and truck parts alone required 30% of consumption in 1990. About three quarters were nylon 66. The remainder was mostly nylon 6, with small quantities of nylon 11 (11-aminoundeconoic acid) and nylon 12 (laurolactam) used in fuel system parts. Most of the remaining uses in molded items include electrical parts (especially connectors), small parts for appliances and machinery of many kinds, household hardware and furniture, and parts for other consumer items. Nylon development work goes on continually for these molded and other uses, yielding forecasts for demand to grow an average of more than 5% annually.

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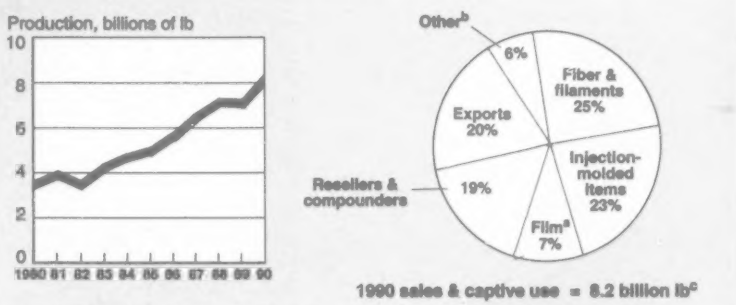
Polypropylene: recycling, declining exports could slow growth

U.S. demand for polypropylene in 1991 is expected to decline slightly. Growth in demand probably will resume next year, but at a slower pace than between 1980 and 1990 when growth averaged 8% annually. Average growth in the first half of the 1990s will be 5% annually, or 2 to 2.5 times that of the gross national product. By 1995, U.S. domestic demand is expected to exceed 8.5 billion lb.

In 1990, U.S. demand for polypropylene was more than 6.6 billion lb. Exports of over 1.6 billion lb brought total demand to some 8.2 billion lb for another record year. The larger markets are in fibers and filaments, injection-molded items, and film.

The development of new grades, to render the resin more competitive with other materials and open new markets, will boost growth in demand for polypropylene, says David A. Durand, plastics market research manager for Shell Chemical. Recycled material would be the most important deterrent to growth, as the whole effort on plastics recycling expands beyond high-density polyethylene, thermoplastic polyester, and polystyrene to include large quantities of polypropylene.

However, exports also could decline and slow production growth of polypropylene. In the next five years, more than 11 billion lb of capacity will be built outside the U.S., Durand estimates. Much of the additional capacity will be in the Pacific Rim region, currently an area of high imports of polypropylene from the U.S. He forecasts that exports will decline at the rate of 9% annually through 1995.



a Less than 0.010 inch. b Blow molding, sheet (more than 0.010 inch), extrusion coatings, and all other. c Including imports. **Source:** Committee on Resin Statistics of the Society of the Plastics Industry

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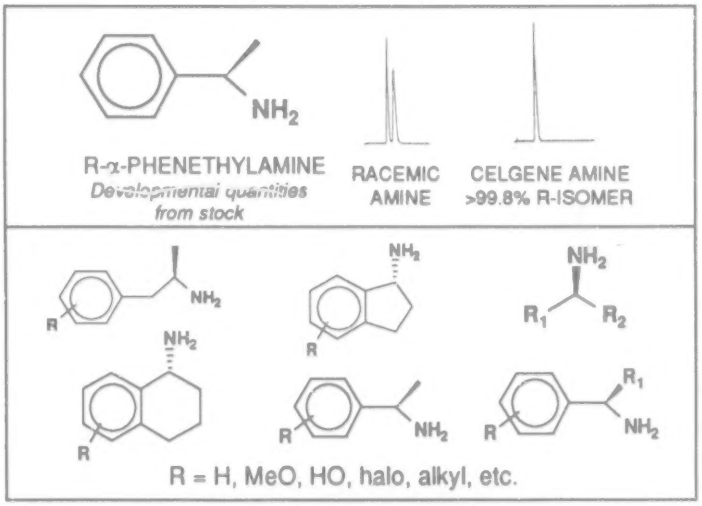

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Extrusion fabrication uses take another 25% of nylon resins. Film, often laminated with other plastic resin film, goes largely to many packaging uses that take advantage of properties such as low gas transmission and easy thermoforming. At above 5% annually, growth in films is expected to be high, especially for coextrusions and biaxially oriented forms.

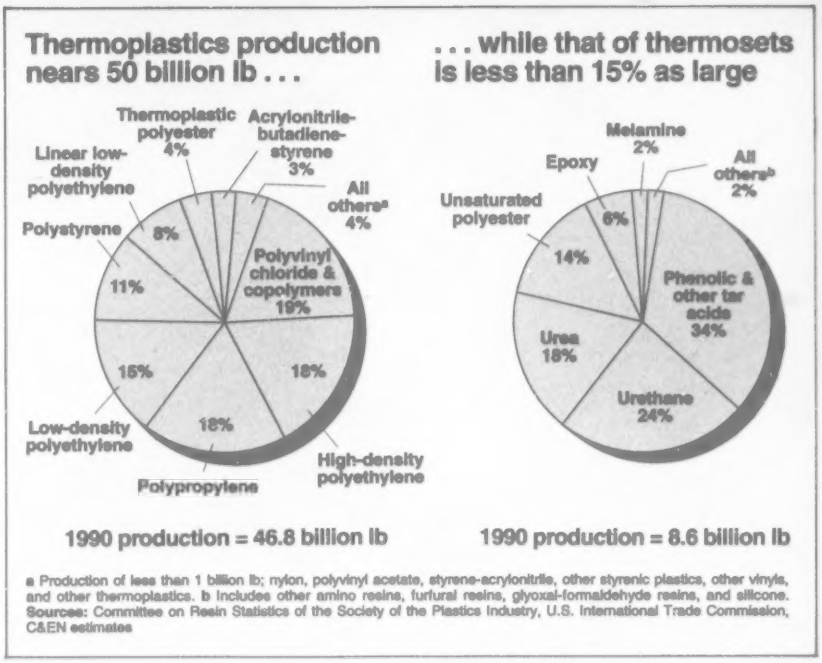
Other extrusions include nontextile monofilaments used in bristles, fishing line, grass trimmer line, and woven support forms for waistbands of trousers. Extruded tubing of nylons is used to carry air and other fluids or as sheathing for steel cable. Nylon resins may be added over other plastic covering of wire and cable to provide better abrasion resistance. Nylons other than 66 and 6 often are used in extrusions. Use of these other extrusions is expected to grow at rates averaging about 5% annually, slightly less than that for film.

Thermoplastic polyester is the other largest thermoplastic having production and consumption data compiled by SPI. After this resin became commercially available in the mid-1970s, production grew unabated until 1989, when output slipped 1.3% because increased prices made it

less competitive with other packaging materials such as aluminum and glass. During the 1980s, however, output zoomed from 500 million lb to more than 1.6 billion lb for an average growth rate of 14% annually.

Bottle grades of thermoplastic polyester accounted for 70% of domestic consumption in 1990. Film and engineering resin uses took the remainder. Soft drink bottles, especially the 2-L size, now continue to grow, but at a slower rate than in the mid-1980s. The major growth now is mostly in containers for foods, liquor, wine, toiletries, and other consumer products.

Polyester resins have a strong competitor in glass for smaller size bottles, such as half-liter (16 oz) bottles for soft drinks. The beer bottle/can size of 12 oz provides even greater competition, so a major move by polyester resins into these containers has been stymied. Because of concern over whether consumers will separate plastic, glass, and aluminum containers, recycling of polyester used in containers is uncertain. Other concerns are the recycled uses for polyester, which replace virgin material.


Thermoplastics production nears 50 billion lb . . .
Thermoplastic polyester 4%
Acrylonitrile-butadiene-styrene 3%
Linear low-density polyethylene 8%
All others[a] 4%
Polystyrene 11%
Polyvinyl chloride & copolymers 19%
15%
18%
18%
Low-density polyethylene
High-density polyethylene
Polypropylene
1990 production = 46.8 billion lb
. . . while that of thermosets is less than 15% as large
Melamine 2%
Epoxy 6%
All others[b] 2%
Unsaturated polyester 14%
Phenolic & other tar acids 34%
Urea 18%
Urethane 24%
1990 production = 8.6 billion lb
a Production of less than 1 billion lb; nylon, polyvinyl acetate, styrene-acrylonitrile, other styrenic plastics, other vinyls, and other thermoplastics. b Includes other amino resins, furfural resins, glyoxal-formaldehyde resins, and silicone.
Sources: Committee on Resin Statistics of the Society of the Plastics Industry, U.S. International Trade Commission, C&EN estimates

About a fifth of the thermoplastic polyester resins consumed in the U.S. is fabricated into biaxially oriented films. The largest use is in various kinds of photographic films in-

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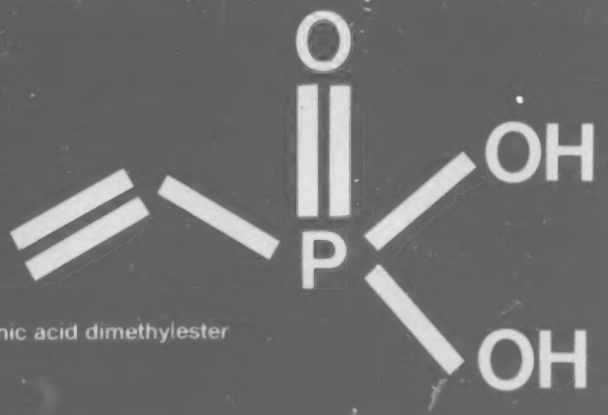

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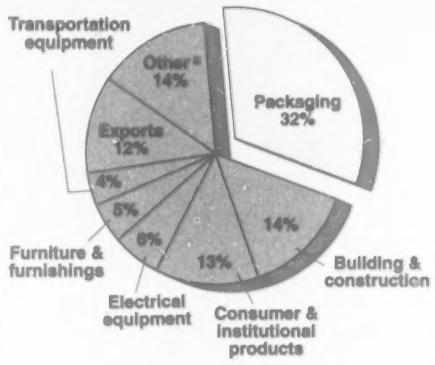
cluding x-ray film. But because this use is growing slowly, it soon could be surpassed by electronic media tapes. Videotape growth has slowed because its base has become so large, but the physical volume growth is forecast to continue.

A large group of other applications round out film uses. None of the miscellaneous uses are growing as fast as electronic media applications, but the miscellaneous uses do exceed photographic film uses. Packaging uses rank first among the miscellaneous group, with most going to food packaging. Other uses include numerous electrical applications (because of insulating and strength properties required), graphics and reproduction, various kinds of pressure-sensitive tapes, and metallized films. As a group, this use of polyester resins is forecast to grow 3 to 5% annually.

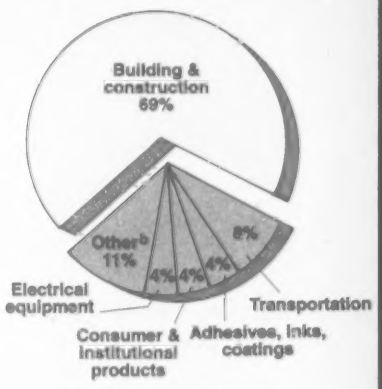
The remaining thermoplastic polyester resins are used as engineering resins, including the butylene and ethylene forms. The fastest growing segment of engineering resins is blends and alloys with other plastics, most of which are ultimately fabricated into parts for automobiles such as bumpers, other body parts, and numerous under-the-hood parts. Other uses are parts for appliances, electronic and electrical devices, industrial equipment, and machinery. Because of a surge in automotive applications (current-

Packaging accounts for nearly third of thermoplastics use . . .



1989 sales & captive use = 46.3 billion lb

. . . and building, construction over two thirds of thermosets



1989 sales & captive use = 6.3 billion lb

Note: Selected large-volume thermoplastics and thermosets; 1990 data not available yet. a Includes adhesives, inks, coatings; industrial equipment and machinery; volumes sold to resellers and compounders; and not classifiable elsewhere. b Includes furniture and furnishings, packaging, industrial equipment and machinery, exports, volumes sold to resellers and compounders, and not classifiable elsewhere. Source: Committee on Resin Statistics of the Society of the Plastics Industry

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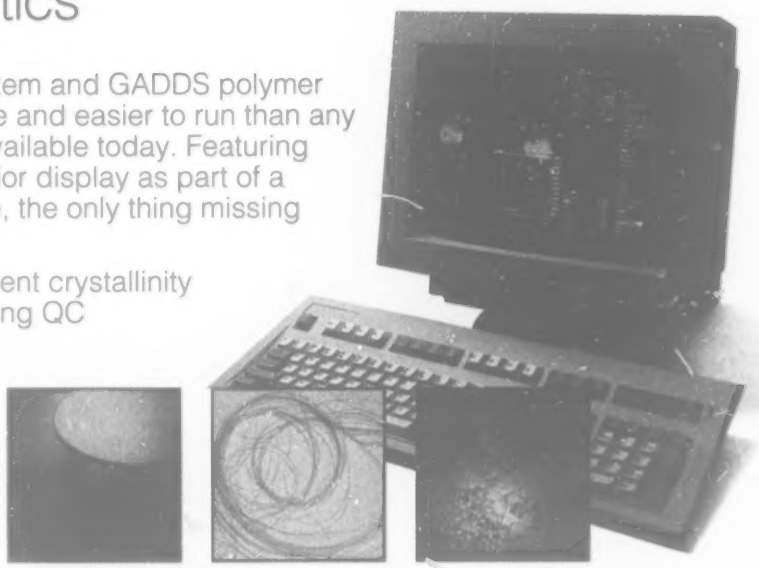

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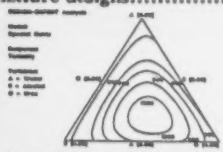

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Product Report

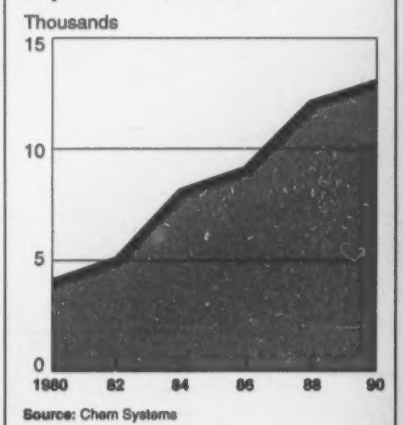
ly dampened by the slump in auto production), growth in use as an engineering resin will be 5 to 10% annually for the next few years.

Among the large-volume thermoset resins for which data are available, epoxy and urea/melamine resins also are having another down year. Both of these groups of resins had relatively poorer sales growth in 1990 than the major thermoplastics and this year the outlook for the two calls for a decline as well. These resins have large uses in the building and construction and the transportation industries, and total demand is heavily influenced by these applications.

Exports are important to demand for epoxy resins, taking about 20% of the total in 1990. During the first quarter of this year, exports of epoxies increased slightly and were the only bright spot among the various uses.

More than half of U.S. consumption of epoxy resins is accounted for by coatings. Earlier this year, use in coatings dropped 5 to 10% as auto production declined. Because of the continued weakness in sales of autos, demand for epoxy resins for coatings will be flat this year, say officials at Dow Plastics, a business group of Dow Chemical. Demand in other markets, however, will mean a modest growth for these resins through 1992. Overall, this translates into a projected 3 to 4% growth in the use of epoxy resins during the next two years, says Thayne Hansen,

Number of polymer grades tripled in the 1980s



Source: Chem Systems

market group manager for Dow's coatings group.

Uses of epoxy resins in various kinds of reinforced composites and laminates are next in size, at more than 20% of total U.S. consumption. In recent years, demand for composites has grown between 10 and 20% annually, according to the Suppliers of Advanced Composite Materials Association. The growth rate is expected to slow, however, as the base gets larger.

Laminates are used in printed circuit boards for electronics equipment. Other epoxy resins are used as molding compounds for semiconductor encapsulation. The current downturn in demand for epoxy resins in electronics applications is expected to gradually turn around, says Kenneth Hawthorne, market manager for electron-grade thermoset resins at Dow Plastics.

Future growth rates will not be in the double-digit range. Between now and 1995, Hawthorne puts the growth for epoxy resins in laminates at between 3 and 5% a year and for encapsulant resins at 5 to 6% a year for an average of 4 to 5%. Among the reasons Hawthorne cited for the slower growth are further miniaturization of electronic equipment and some saturation of markets. Thus, he doubts there will be a need for additional capacity to make these epoxy resins.

Mobay's nylon 6 resin replaces steel in in-line roller skate frames

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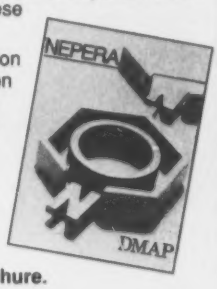

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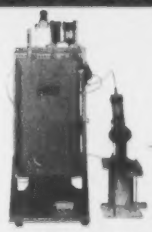

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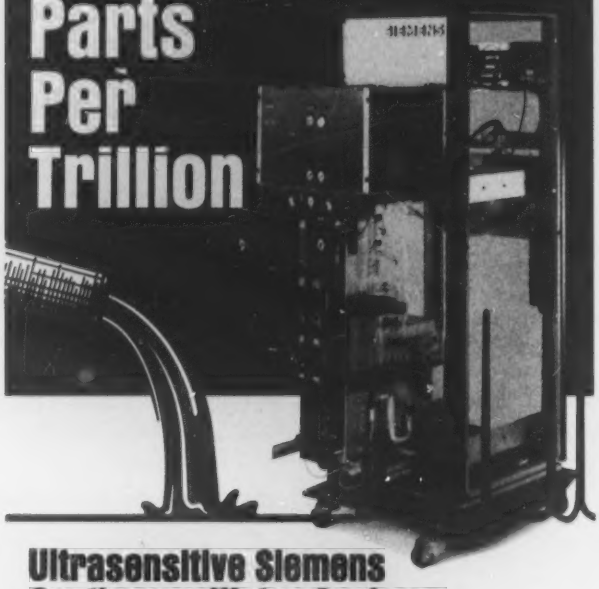

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mats, prior to the addition of asphalt to make roofing shingles, increased rapidly as this kind of shingle replaced others. However, this type of roofing shingle has captured about as much of the market as it can.

Some uses, such as in paper and textile coatings, face competition from other resins. Urea resins impart wet strength to paper but are being replaced by other materials. Textile use also declines as these resins are replaced by materials that do not have the potential toxicity of formaldehyde. Growth prospects are low because of the maturity of most of these uses.

Melamine resins cost more than urea resins, but they have better resistance to moisture and temperature extremes and have greater hardness when cured. Because of these properties, their largest use is in coatings, generally in complex systems from which high performance is expected. For example, they may be combined with epoxy resins in primers for automotive use and with acrylic resins for auto top coats. In a similar fashion, melamine resins go into coating systems for appliances, metal containers, machinery, and coil coatings.

Of other uses of melamine resins, decorative and other laminates rank second, followed by paper treating and coating. Both high- and low-

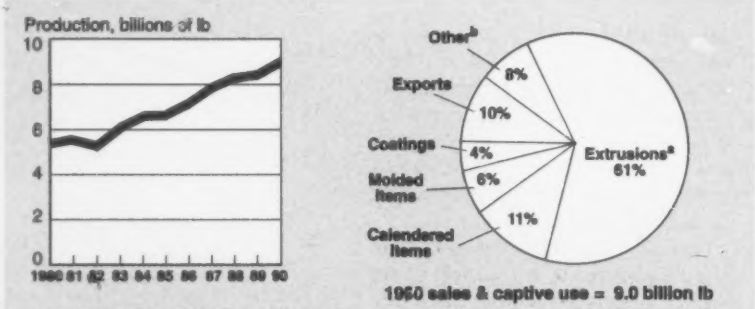
Phillips 66 technician inspects styrene copolymer containers

PVC: extruded products support growing demand

Production of polyvinyl chloride (PVC) has grown steadily since 1982, but the recession is causing slippage this year. If they persist, the output declines early this year could be too much to overcome a decline in 1991 despite improved demand this fall. Early estimates place 1991 output down 3%, or about 300 million lb, from 1990 output of 9.1 billion lb.

But production is expected to grow after this year, as demand recovers in the U.S. In contrast, global demand will slow in 1991 and is forecast to grow later at a compound annual rate of 3.7%, to bring the total to 58 billion lb in the year 2000, says Richard H. Roman, manager of marketing and business research in B. F. Goodrich's Geon Vinyl Division.

Over the past several years, global demand for PVC has increased 4 to 5% annually, bringing it to about 40 billion lb in 1990. This growth is about 2 billion lb per year, roughly equivalent to the capacity of four new PVC plants and two world-scale vinyl chloride plants, Roman points out. Plant utilization in 1990 stood at a relatively high 93% of effective capacity. (Effective capacity accounts for actual operating conditions that reduce output from nameplate or design capacity.)



a Includes pipe and tubing, siding and accessories, wire and cable covering, and film and sheet. b Paste processes (except coatings), resellers and compounders, and all other. Source: Committee on Resin Statistics of the Society of the Plastics Industry

Exports contribute strongly to demand, accounting for about 10% of the total. Roman forecasts that exports from North America will continue to be strong during the 1990s because of a cost advantage. Capacity will continue to be short in the Asia/Pacific region, causing the region to be a net importer of PVC throughout the decade.

pressure laminates (related to curing conditions) are widely used in housing and commercial buildings as countertops, panels, and furniture parts. Demand for these laminates depends on housing construction and remodeling and ancillary activities such as furniture purchases. Demand this year is forecast as being soft again.

The other uses of melamine resins also have low growth prospects for this year. Paper-treating uses depend on demand for higher quality papers, a use that slowed as a result of the recession. Competition from other resins such as styrene-butadiene and polyvinyl acetate latices reduces growth prospects. Other uses in molding compounds, plywood resins (often blended with urea resins), and many smaller uses will grow at low rates and not have significant impact on total demand.

A large number of other plastics are produced and consumed globally. Data on their production and consumption vary in availability and reliability. Some of these plastics have been commercially available for many years, and others are just entering commerce. Some of these polymers were developed for

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Phenolics: mature products, lacklaster outlook

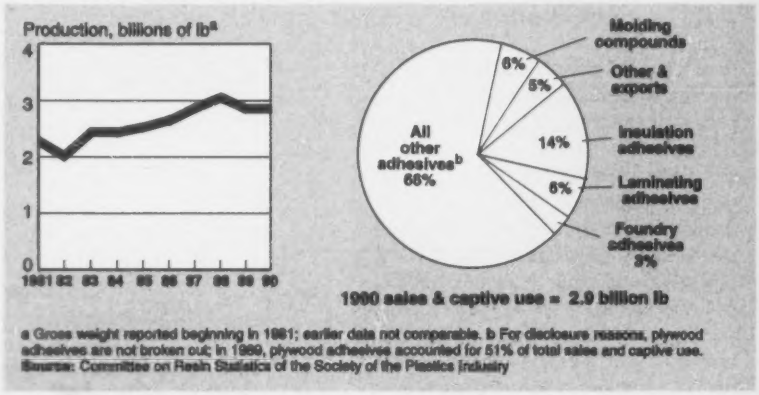
Demand for phenolic and related tar acid resins could drop 10% in 1991, following four years of nearly flat demand. Phenolic resins, which include some of the oldest known plastics, are very mature products. Hence, future production growth is expected to be modest beginning next year.

Phenolic resin production and sales data are reported by the Society of the Plastics Industry on a gross basis that includes the weight of solvents, fillers, and colorants. Actual resin content varies widely—from 40 to 80% solids content, depending on use.

Plywood adhesives typically take more than half of U.S. consumption. As a result of disclosure problems, data on consumption in plywood are no longer available. Similarly, data on use in making fibrous and granulated wood board have not been available since 1987. Before that year, this use was reported as accounting for about 10% of U.S. consumption.

These adhesives and others used in insulation materials (more than 10% of consumption) eventually end up in buildings of various kinds. Construction (more than 80% of the end market for phenolic resins) began to slow in 1989 and demand for phenolic resins turned down. A recovery may begin in 1991, but the resumption of annual growth will only come in 1992, says Kenneth H. Brockschmidt, product manager at Georgia-Pacific.

All other uses of phenolic resins total 10 to 15% of consumption. Because of their small size, these other uses won't significantly affect demand even though their growth rates surpass that of the gross national product.



a Gross weight reported beginning in 1981; earlier data not comparable. b For disclosure reasons, plywood adhesives are not broken out; in 1989, plywood adhesives accounted for 51% of total sales and captive use.
Source: Committee on Resin Statistics of the Society of the Plastics Industry

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MAKING THINGS WORK

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specific uses and then found to have many other uses, spurring growth in demand. Others, also developed for specific uses, were found to have one or more deficiencies (high cost being prominent) that have held down growth or were replaced by other plastics or materials.

Polyurethanes are one of the largest in this group. Almost 3.3 billion lb of materials, including isocyanates, polyethers, polyesters, blowing agents, catalysts, fillers, and other additives, were consumed in 1989 (latest year data were available) in urethanes, according to SPI data. More than half of urethane output in 1989 was flexible foam, 26% rigid foam, 5.4% coatings, 6% adhesives and sealants, and 9.5% elastomers.

The urethane use pattern is diverse. More than 17% of urethanes went into construction uses in 1989, almost 23% into transportation, 19% into furniture, and 10% into carpets, with appliances, packaging, bedding, and miscellaneous uses accounting for the remainder.

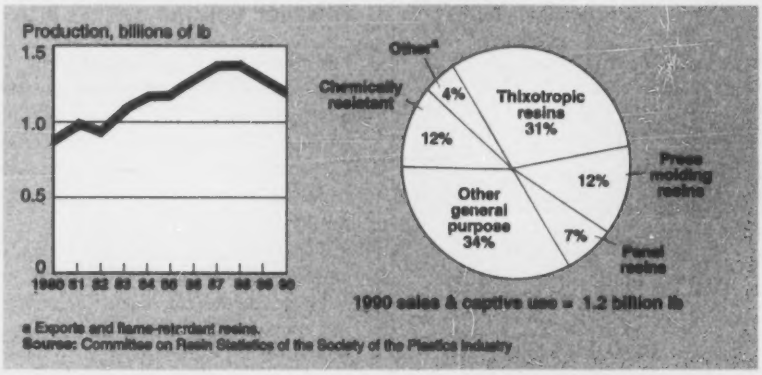
Production, sales, and use of the urethane materials grew until 1989, when a downturn occurred for some and minimal growth for others. The outlook for this year is for flat de-

Unsaturated polyester: output continues to fall

Slowing demand for many kinds of durable goods continues to affect unsaturated polyester resins. Output this year could fall more than 10%, following a 7% drop in 1990. A pickup next year is expected, but a return to production of more than 1.4 billion lb (as in 1988) is not likely.

A large share of this group of resins is used in products considered to be luxury items or descretionary spending items. About 80% of the resins are used with reinforcements (such as glass fiber) in building components such as bathroom fixtures, underground tanks, boats and accessories, and automotive parts. The remainder goes into nonreinforced products.

These resins are made largely of an acid component, a glycol, and styrene. Phthalic and maleic anhydrides dominate the acid components and propylene glycol dominates the glycol group.



Styrene and a few other unsaturated hydrocarbons make up the rest of the materials used.

Products made of unsaturated polyesters have varied with the ebb and flow of interpolymer competition. For example, use in microwave cookware boomed in the mid-1980s, but since has been largely replaced by thermoplastics. More recently, auto engine parts are being made of these resins.

Other engine parts could be made from these compounds because they withstand temperatures now being encountered under automobile hoods and allow fast cycling times for injection molding, says John S. Holroyde, director of sales for thermoset composite molding compounds at American Cyanamid. Holroyde forecasts that growth in use of such compounds will be 10 to 15% annually.

mand since most end uses are in housing and transportation—markets that are having off years.

Excluding naturally occurring resins, synthetic plastics have been coming to market for 125 years. Cellulose nitrate is often cited as the first commercial plastic developed, with liquid crystal polymers and polymethylpentene among the most recent entrants in the marketplace.

Alloys and blends of plastics long ago became recognized as routes to properties not so economically obtainable in single resins. A few of these mixtures were known before World War II, but most have been developed since 1950, says Joel H. Levy, senior market research analyst at Allied-Signal's Engineered Plastics Group. Nevertheless, this segment of the plastics industry is not mature; almost daily new alloys and blends come to market and new producers enter the marketplace.

Alloys differ from blends in the molecular forces involved, says Levy. Alloys have a tighter, denser molecular structure. They also have some significantly improved properties—a synergistic effect—in comparison to the individual compo-

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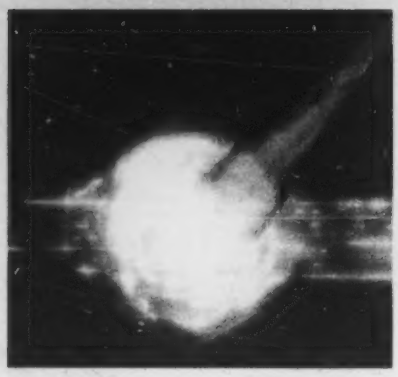

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Smaller volume resins found in most use areas

For more than a century, chemists in laboratories worldwide have developed a large number of polymers. A relatively few have been commercial successes, but efforts continue unabated to find additional commercially important plastics.

Following are some examples of smaller volume plastics that have met modest commercial success, according to the Society of the Plastics Industry.

Acetals (made from formaldehyde) used in parts for automobiles, consumer products, and machinery.

Acrylics (made from acrylic and methacrylic esters) used in auto parts and glazing.

Alkyds (made from organic esters and aromatics) used in automotive and electrical parts, and coatings.

Cellulosics (made from cellulose and organic acids) used in packaging, parts for automobiles, and consumer products.

Coumarone-indene resins (made from coumarone, indene) used in processing aids, extenders, and plasticizers.

Fluoropolymers (made from halogenated olefins, olefins) used in parts for electrical/electronic equipment, tubing, and coatings.

Nitrile resins (made from acrylonitrile, esters, butadiene, styrene) used in packaging.

Petroleum resins (made from mixed unsaturated monomers recovered from petroleum processing streams) used in adhesives, coatings, inks, and processing aids.

Polyamide-imide resins (made from trimellitic anhydride, aromatic diamines) used in parts for aerospace, automobiles, and machinery.

Polycarbonates (made from bisphenol A, diphenyl carbonate, phosgene) used in parts for appliances, consumer goods, and electrical equipment.

Polyimides (made from dianhydrides, diamines, diisocyanates) used in parts for autos and electronic equipment.

Polyphenylene oxide resins (made from xylenol) used in parts for appliances, automobiles, business machines, and electrical/electronic equipment.

Polyphenylene sulfide resins (made from *p*-dichlorobenzene, sodium sulfide) used in parts for autos, electrical/electronic equipment.

Sulfone resins (made from bisphenol A, substituted sulfones, potassium hydroxide) used in parts for autos, and electrical/electronic equipment.

nents. Properties of blends generally are the average of those of the individual components.

Alloys are relatively newer, says Levy. A surge in patents attests to the importance plastics producers give to obtaining a proprietary position in supplying these materials. One recent development in technology for making alloys—"compatibilizers"—is used to promote greater chemical bonding and reactive processing during compounding.

Levy cites three types of alloys and blends expected to grow significantly in use through 1995. Nylon-based alloys and blends with polyolefins, elastomers, and other materials will grow from 66 million lb in 1990 to 91 million lb in 1995, for a compound annual growth rate of 6.6%. Polycarbonate alloys with polybutylterephthalate, ABS, and other materials will grow from 135 million lb in 1990 to 196 million lb in 1995, for a rate of 7.7% annually. Various polyester alloys also will grow from 41 million lb in 1990 to 70 million lb in 1995, for a rate of 11% annually.

Methods for achieving success in the alloys/blends segment are similar to those for the whole plastics industry. A proprietary system of compatibilizer, polymerization, additives, and fabrication are technical requirements, points out Levy. Marketing requirements are clear targets for end uses and strong end user support. Where possible, economic requirements are captive resin supply and large-volume markets. □